Industrial ecocycles: rate adjustments and dematerialization

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Industrial ecocycles: rate adjustments and dematerialization

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Although considerable improvements have been made in energy use over the preceding decade or so, by fuel savings and conservation, achievements in the reduction of the materials used per unit of service delivered have failed to match these. Indeed, in some situations, the reduction in energy use has necessitated consequent increases in material commitments. However, recently there has been a sharper focus on reducing material inputs, both by alterations in product design and service life adjustments. Technological development will allow considerable further advances in such dematerialization and goals of a 'factor four' or even a 'factor ten' have been set. However, the need to include both economic and social considerations along with such objectives has not been a notable feature of such thinking and developments. The potential for rate adjustments and dematerialization will be explored and the likely bottlenecks will be identified and discussed.

1. Introduction

It is intriguing, indeed perhaps even paradoxical, that two, at first sight opposite, arrays of concern have converged to effect rate adjustments of industrial ecocycles and bring about the beginnings of a process of dematerialization. On the one hand, over the last 15 years, acceptance of the role of recycling in materials supply, substitution of new materials and innovation resulting in new technologies have combined to give a reduction in the use of resources, manifest in a declining materials intensity. This has been mirrored by a reduction in demand for certain metals and mineral ores, accompanied by a halving of their average real price. On the other hand, dematerialization has been encouraged by a different set of pressures: concern over depletion of resources and the environmental degradation that occurs from the waste streams that result from seemingly profligate use of these resources. Public pressure, environmental legislation and changes in consumer behaviour have been part of another driving force encouraging dematerialization.

It is interesting that when the intensity of use of materials is compared with increases in per capita Gross Domestic Product (GDP), certain long-term trends in different regions of the world and over a range of metals and other commodities become apparent. Part of this trend is towards dematerialization as the amount of raw material per unit of 'service' delivered (the material intensity) declines. There has been a rate adjustment in the system.

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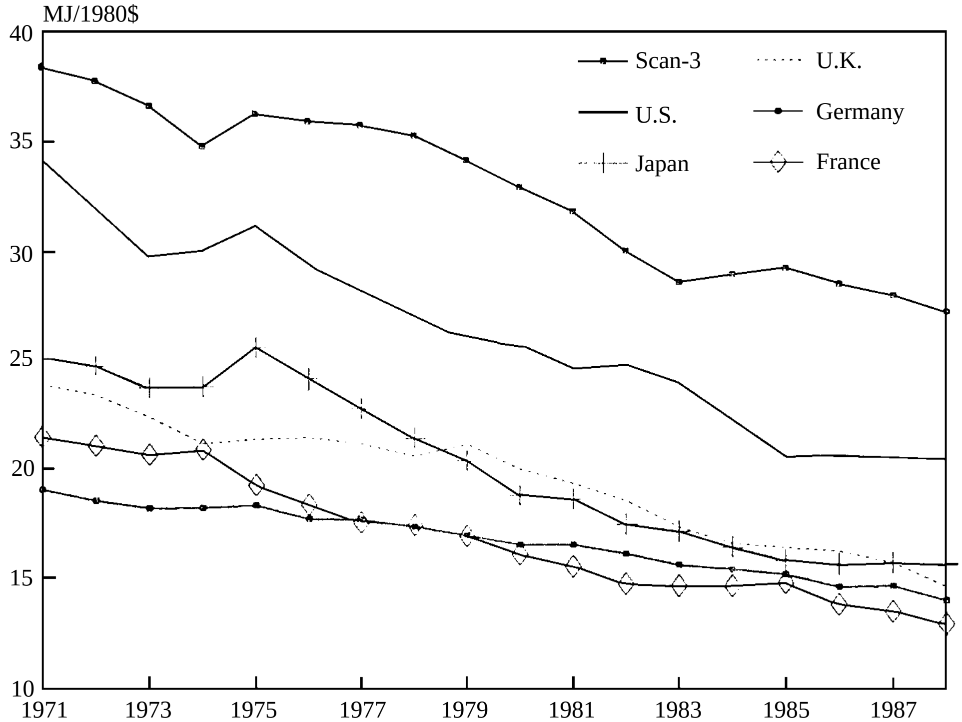

Figure 1. OECD manufacturing energy intensities.

This declining materials intensity, driven by somewhat disparate pressures, will be explored in this paper beginning by consideration of the better-known energy intensity trends. After an analysis of the global scope and nature of reduction in materials intensity, in a number of sectors, a brief consideration of the relationship between energy and materials intensity trends will be undertaken. Finally, the way in which technological, social and economic features impinge upon trends in materials intensity will be discussed.

2. Energy intensity

A common feature of all industrial processes is the requirement for an energy supply and it is in the realm of energy use that the most remarkable declines in intensity have been achieved. In OECD countries, manufacturing energy intensities declined significantly between 1971 and 1988 (figure 1); overall, travel aggregate energy intensity in the USA, Japan, West Germany, France, the UK, Italy, Sweden and Norway also declined, by 13%, between 1973 and 1988; the appliance electricity use per capita showed a decline in the USA, West Germany and Norway by 13, 2 and 4%, respectively, between 1973 and 1987. The energy intensity of GDP for three OECD countries is shown in figure 2 and the divergence between the growth rate in the GDP and the total primary energy supply in the OECD between 1973 and projections to 2000 are shown in figure 3. This has led to the recognition of low energy use scenarios (Colombo & Bernardini 1979)

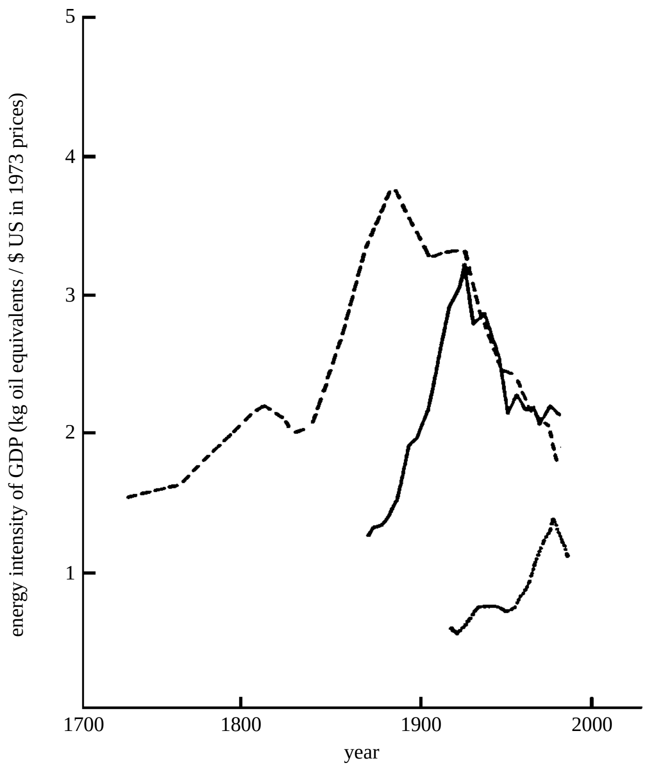

Figure 2. Energy intensity changes over time: - - -, UK; ——, USA; · · ·, Italy. (Reprinted from Bernardini & Galli (1993) with permission from Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington OX5 1GB, UK.)

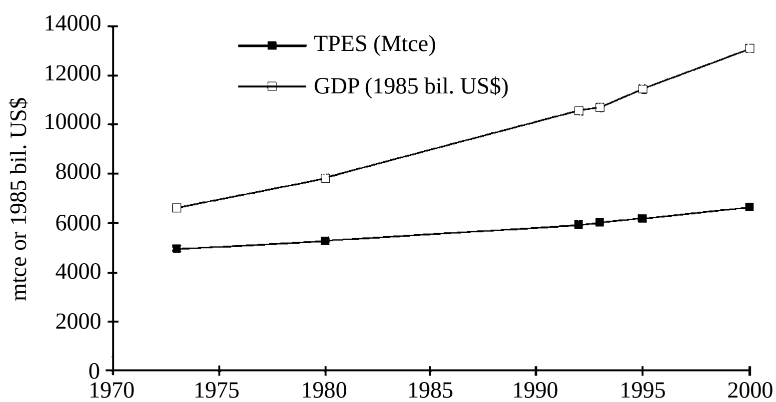

Figure 3. GDP and total primary energy supply (TPES) of OECD countries.

3. Materials intensity

An analysis of the long-term trends in the intensity of use of materials (Bernardini & Galli 1993) identifies three major determining factors: changes in structure of final demand, increases in the efficiency of materials use and the substitution of alternative materials. These factors are related in an overall use and fall in materials consumption compared with the annual GDP. For example, where, initially, consumption is low

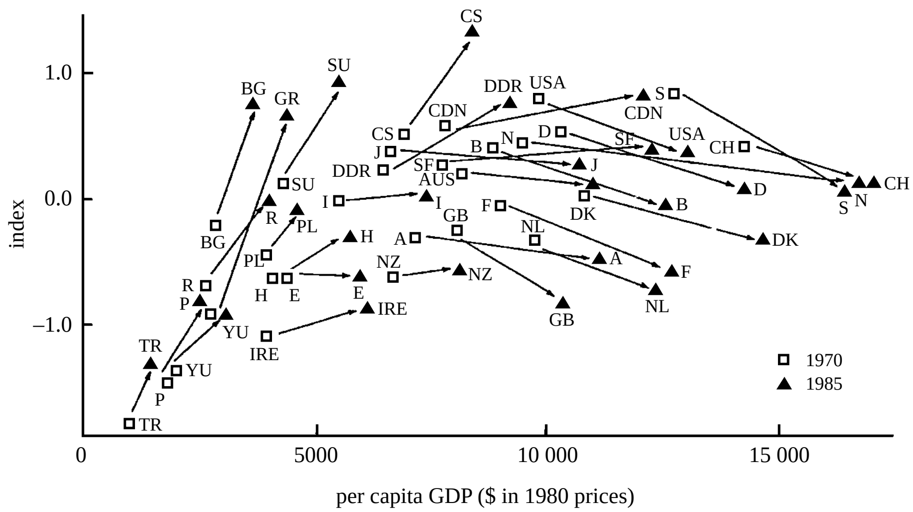

Figure 4. Index of structural environmental impacts as a function of per capita GDP in 1970 and 1985 (Jänicke *et al.* 1988).

but the market large, then demand rises and continues to do so even as competition increases, leading to product quality improvement and reduction in the unit price. But as markets become saturated and growth in consumption declines, materials use declines also. Manufacturing response, to cut costs, in terms of increase in the efficiency of materials use, including recycling, and substitution of other materials in the production process, leads to an intensity reduction.

Bernardini & Galli (1993) cite the reduction of one hundredfold in the weight to power ratio of industrial boilers since the early 19th century as an example of increased efficiency in materials use; estimates from 1967 (EPA 1973) and 1990 (Rogich 1992) suggest that over a nearly 25 years' span, recycling of (i) iron and steel, (ii) aluminium and (iii) lead, copper and zinc have increased from 31–56%, 18–43% and 39-60%, respectively. Substitution of materials, such as the replacement of steel by aluminium, plastics and fibreglass, improvements in aluminium alloys, now used in beverage cans, optical fibres for copper and high fructose corn syrup (HFCS) for sugar all lead to a materials intensity reduction (OECD 1989). Bernardini & Galli (1993) give other examples.

Malenbaum (1978) was the first to point out that an analysis over the period 1950–75, of ten regions, of 12 metals, shows that the long-term trends in use of resources were repeated in all economies. Following initial rises there was a decline in materials use intensity over time with increasing GDP. In 1980 prices, the peak seems to fall around US $10 k per capita (figure 4). Bernardini & Galli (1993) suggest the bell-shaped relationship between per capita GDP and intensity of use is similar in many economies, although the later the peak is attained, in real time, the lower the intensity of use achieved (figure 5). Evidence has also been presented of a subsequent use again giving an N-shaped curve (Bruyn & Opschoor 1994).

4. Energy intensity and materials intensity linkages

There are obvious ways in which energy use intensity and materials use intensity are linked. It is reasonable to link greatly reduced material consumption in the man-

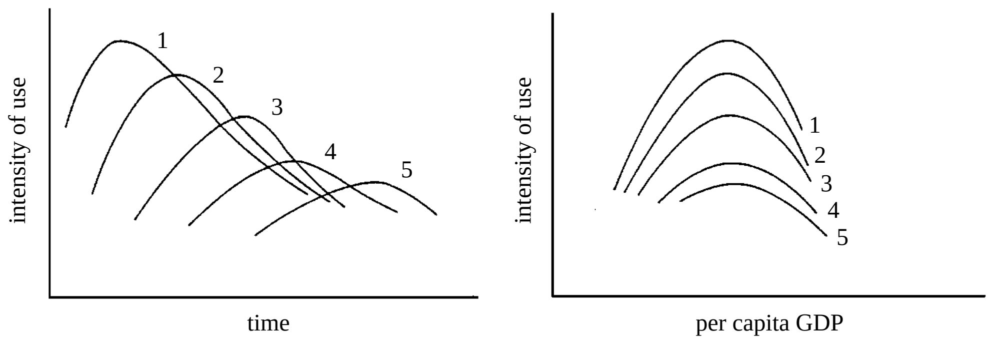

Figure 5. Figurative description of the theory of dematerialization. Countries 1–5 complete development in subsequent periods of time at around the same value of per capita GDP. The intensity of use of a given material declines the later in time each country completes development. (Reprinted from Bernardini & Galli (1993) with permission from Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington OX5 1GB, UK.)

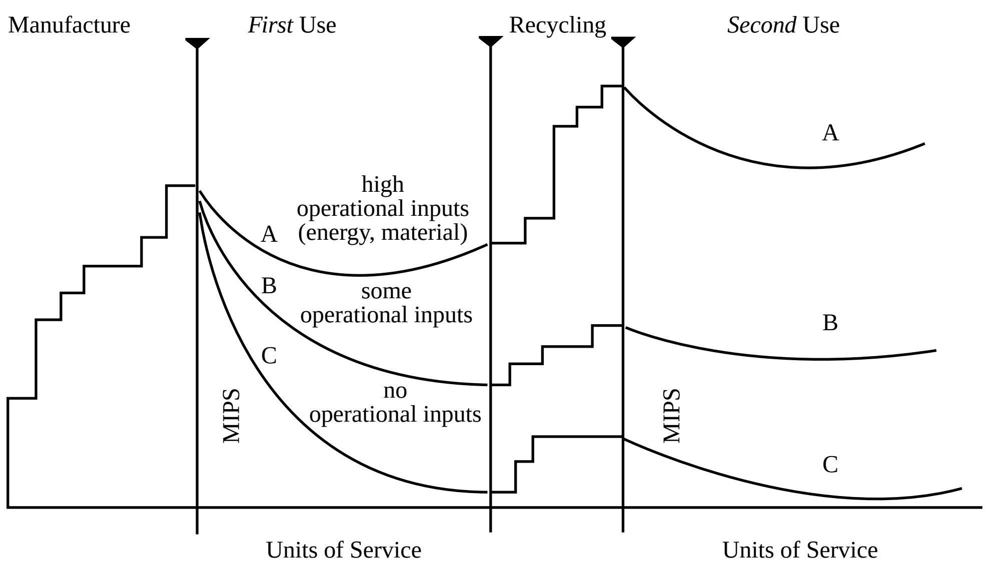

Figure 6. Inputs in relation to unit of service from manufactured and recycled goods (Schmidt-Bleck 1994).

ufacture of a product with a lower energy requirement. But not all reductions in intensity are mutually reinforcing. Energy conservation through, for example, home insulation requires added material inputs (in roof insulation, triple glazing and cavity wall insulation). Improved materials intensity through recycling has energy and other costs (figure 6). Replacement of CFCs and HCFCs by substitution of Cl and F intermediates leads to a higher energy use intensity. Reductions in transport energy use intensity in one activity (say, travel to work) may result in increases by other travel activities (say, leisure or tourist travel).

There can be no automatic assumptions relating to the reinforcement or trade-off between reductions in intensity of one factor in comparison to that of another. Detailed analysis and auditing are required.

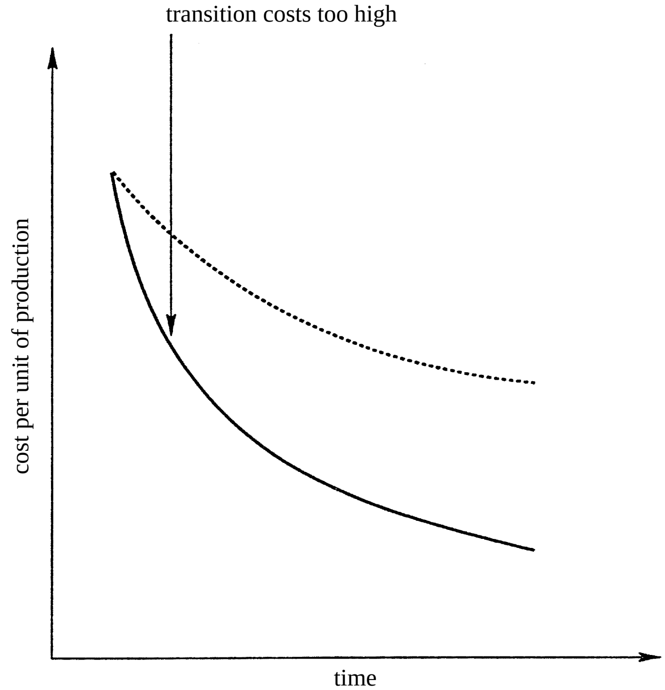

Figure 7. Costs per unit of production in relation to a change in the technology employed.

5. Technological, economic and social factors

(*a*) *Technology, economic and social interactions*

If real progress in dematerialization is to be made, and some sources speak of a reduction of a factor of four (Weizsäcker *et al.* 1997) and even a factor of ten (Schmidt-Bleek 1993), then amongst other instruments, not just minor changes in technology but high levels of technical innovation will be required. *Induced Innovation Models*, based on neoclassical economic theory, emphasize the role of prices in determining incentives to innovate and bring about technical change. If a shift in relative prices could be met by, for example, innovations bringing about savings in labour or capital, then technical innovation would be induced. Although this describes what does occur, innovation 'take-up' varies from one country to another, between cultural groupings, from one industrial sector to another, between management systems and according prevailing economic conditions, as instanced below:

innovation penetration

slow ... *rapid*

building agriculture pharmaceutical electronics

forestry chemical automotive

The system as a whole exhibits degrees of *technological and behavioural inertia* (Ferrante 1992) that largely results in the adoption of technological changes that rely heavily on using both *environmental resources and services*, and implementing *end-of-pipe technologies* rather than *cleaner technologies*. Induced Innovation Models

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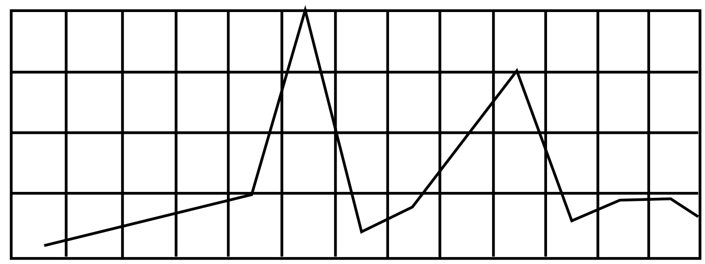

Figure 8. Relative activity in cavity wall insulation in the UK (Shove 1992*a*).

are not convincing descriptions and the system is seen to be more complex than original models allowed. This is mainly due to the interaction that occurs between technological, economic and social factors.

(*b*) *Economic factors*

Changes in technology usually have large capital requirements. In relation to opportunity cost, the *benefits of change* must be greater than the *transition costs* (figure 7). In addition, enterprises must be able to forecast this. Assessments and planning, however, may be faulty. More cautious managements may prefer end-of-pipe solutions that are less costly and simpler to implement in the short term. The environment and common property resources are imperfectly priced and where it is feasible to overuse these, rather than make a technological shift, then there will be a bias in this direction. A particularly perverse example of where transport costs appear too small and environmental impacts valued too low is the 8000 km strawberry yoghurt! The sources of raw materials that go into the production of Germany's favourite yoghurt and the possibility for a reduction in such a high transport intensity have been explored by Böge (1993).

(*c*) *Social factors*

Social factors and their role in innovation inertia have received too little consideration, too late. Technology transfer is often regarded as depending on the exchange of information and ideas between socially anonymous agents of change. However, within the social structure there is potential to *favour* or *inhibit* change, economic considerations notwithstanding.

One example, from the building industry (Shove 1992*a*), will be given. Homes with higher insulation need smaller heating systems and hence have lower fuel bills for the occupants. Yet it is estimated that in the United Kingdom eight million privately owned homes have no cavity wall insulation. Savings to householders in heating bills would be considerable; consequent reductions in CO_2 emissions would be of environmental benefit. Why is this option so rarely adopted? Shove (1992*a*) plots the history of progress (figure 8, table 1). She describes it as a *downward spiral* within the social system comprising manufacturer, installer, government and consumer.

And what of smaller heating systems? Installations in two-bedroomed apartments, which are remarkably energy efficient, are still being fitted with heating units capable of servicing five-bedroomed houses. Why? Three possible reasons are identified: builders were not convinced of the demonstration results and feared *post hoc* consumer complaints; it was cheaper to bulk buy one type (larger) of heating unit; and

Table 1. *'Progress' in cavity wall insulation (Shove 1992a)*

1959–1974	filling the gap
1975–1981	curbing the cowboys
1982–1983	foam fears
1984–1992	fibre wars

years of experience resulted in practices based on 'gut feelings'. Technology transfer is *not* technology providers shipping out knowledge to technology receivers, but a highly selective process that may institute certain barriers and obstacles to the transfer. Technology transfer must view processes of innovation in the context of social structuring. The challenge is not to force technological innovation on reluctant managers but to identify socially appropriate ways of moving from awareness to adoption. Social reality, as well as economic reality, must be part of the equation (Shove 1992*b*).

(*d*) *Technological factors*

Simple models of technological innovation, based mainly on the role of the price system in determining incentives for technical change, do not take account of the fact that enterprises are not always able to select technical innovations in such a way as to minimize cost. This is because: they are committed to past technical decisions in the allocation of resources to their future research effort; they rarely possess perfect information on the full range of appropriate innovations; and enterprises are only able to imperfectly associate a cost to each technological opportunity.

Research and development (R&D) activity is usually targeted. It improves a core technology but also has a spillover effect appropriate to associated technologies. However, as new technologies become more and more specific it becomes more difficult to apply innovations from one field to another. Technological innovation may become localized, selective and substitution possibilities decreased (Ferrante 1992). Costs are cumulative and costs, therefore, are not just associated with developing a new or improved technology but also with giving up the old. Of course, such considerations vary from industrial sector to industrial sector, country to country and, with increasing globalization, from company to company.

6. Outlook

From the converging response to changes in the structure of final demand for materials and mineral ores, and the growing concerns surrounding natural resource depletion and environmental degradation, a number of issues emerge. Certain driving forces on the dematerialization trajectory are variously playing their part.

Often, only rather high taxes (emission taxes) are effective in promoting the technological innovations necessary for significant progress. Individual costs of change are high and fall on relatively few. Benefits are often better distributed, over larger numbers, but are smaller. Hence innovations may lose out to *status quo* lobbyists. Regulation, as long as it is properly enforced, may, in certain circumstances, be more effective, coupled with public R&D money, than direct taxes or subsidies. Indeed, it does appear (in the automotive trade, for example) that dematerialization has received its greatest boost from responding to laws and regulations (Jänicke *et al.*

1988). Regulations reduce the risk to enterprises, engender less opposition than taxes and allow advances to be coordinated. However, instruments to encourage dematerialization need to be specifically tailored for enterprises of different size and industrial sector.

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